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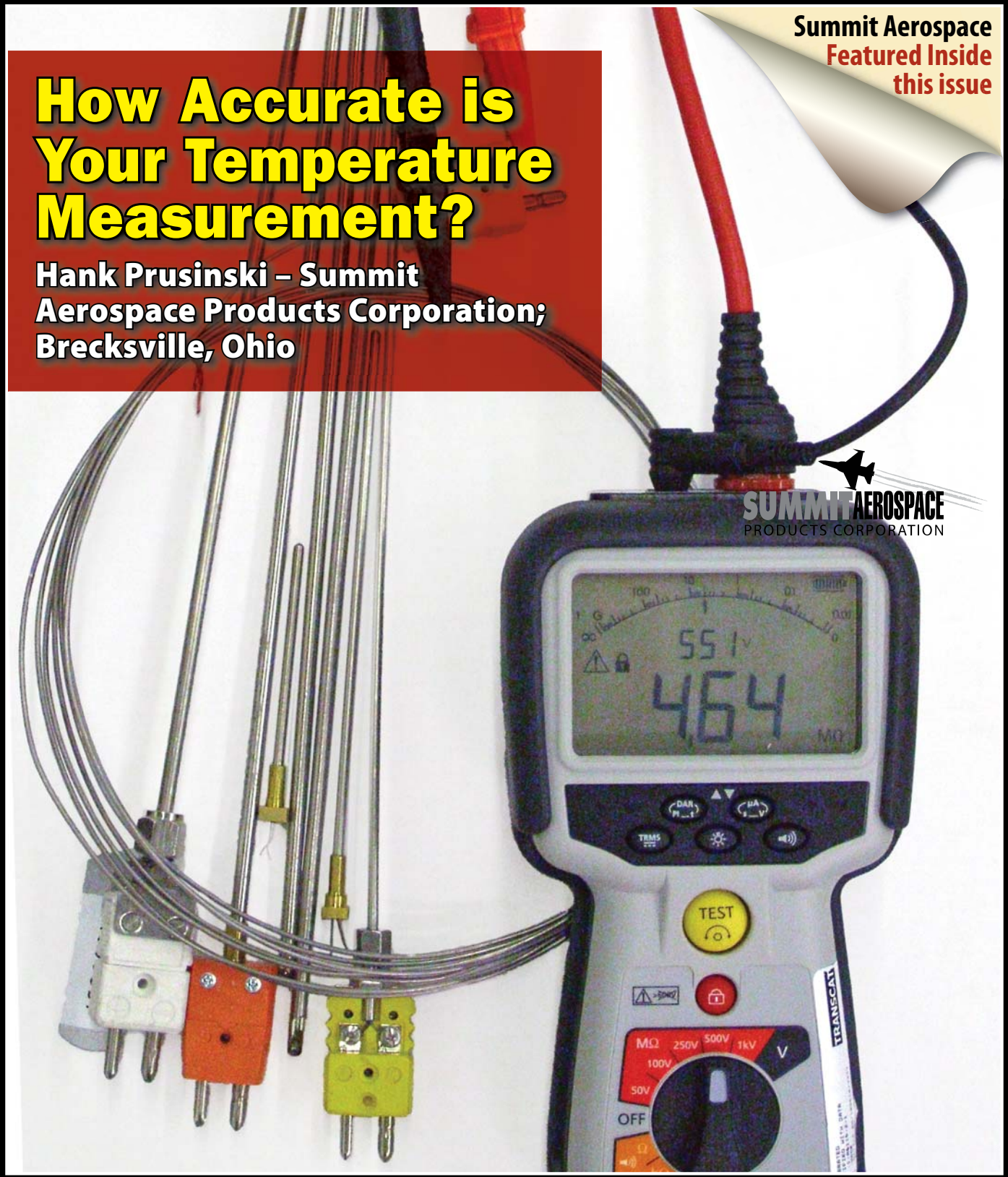
Hank Prusinski – Summit Aerospace Products Corporation; Brecksville, Ohio



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How Accurate is Your Temperature Measurement?

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American businesses have become accustomed to trust any group or company that has the "appearance" of being dependable because it has the endorsement of organizations that will give one for a fee.

The term ISO certified or "Accredited by XXX" has given the impression of guaranteed credibility, honesty and trustworthiness. Often, this paid-for credibility has been earned by companies that could be trusted without any paid endorsements. There is a potential problem with this thought process. A manufacturing company can be "accredited" to certify the accuracy and effectiveness of their own products!

Imagine a meat-packing plant being able to certify their own meat or a drug company being able to approve the efficacy and safety of their own new drugs – with no government oversight or other accountability. Government-run programs are not perfect, to be sure. While there is much waste in established government agencies, there is very little fraud. The system of accountability is such to keep that in check. When fraud is discovered it is usually dealt with severely and publicly.

The private sector, on the other hand, demands accountability of others. That is, until they are the ones being held accountable. Waste in the private sector is not profitable and is not tolerated. Fraud, on the other hand, can be very profitable, and some consider it a normal and acceptable business practice. Some even use it to gain an unfair advantage in the marketplace.

Are Companies Trustworthy?

I am not implying that all self-certifying companies cannot be trusted. The question is, which ones can be trusted and which ones cannot be? By being able to certify the accuracy and effectiveness of your own products, there is always the temptation to "cheat just a little bit" for increased profit, to minimize loss or to be able to offer the lowest price. As a customer, unknowingly buying a product that is misrepresented and is outside of needed and specified tolerances by just a little bit is like the old saying, "You can't be just a little bit pregnant!"

New Purchasing Practices

A further complication is what has happened to business purchasing practices in our new world economy. Long-standing relationships formed in the past between customers and trusted long-time suppliers have taken a far backseat to price. Some companies have turned over all purchasing responsibilities to outside purchasing services that know nothing about the importance of certain purchased items. These individuals and even inside purchasing managers and buyers often care first and foremost about price and delivery and care very little (if at all) about quality. Certifying or accrediting unscrupulous manufacturers who now have electronic access to the world has been taking a toll on quality, dependability, lost product confidence … and, especially for the unwary in industries like aerospace and medical devices, safety.

The eBay-like purchasing mentality is to get what you need at the last minute and get it as cheaply as possible as long as it appears to be OK – even if the lowest price makes no sense. The more hidden the deficits in the purchased product, the more dangerous this becomes. If you buy low-priced machined parts, they may not fit, and the deficit becomes readily apparent. If you buy low-priced products with certified hidden attributes – like temperature sensors – you could be buying a ticking time bomb.

There is a forgotten truth from author and social critic John Ruskin (1819-1900). What was true over 100 years ago is even more relevant in our ever-expanding world today. Ruskin said: "It is unwise to pay too much, but it is worse to pay too little. When you pay too much, you lose a little money – that is all. When you pay too little, you sometimes lose everything because the thing you bought was incapable of doing the thing you bought it to do. The common law of business balance prohibits paying a little and getting a lot – it cannot be done. If you deal with the lowest bidder, it is well to add something for the risk you run, and if you do that you will have enough to pay for something better."

Let's Talk Temperature Sensors

Temperature is so important that SAE Aerospace has written specification AMS 2750D, the Aerospace Material Specification on Pyrometry. This was written to make the aerospace industry's critical temperature measurement for heat treatment standardized, understandable, traceable, repeatable and consistent, regardless of who is doing the temperature measurement. Much thought and work has been put into this 46-page specification because of the critical importance that temperature and its measurement has in manufacturing items for this industry. Even if a sensor user does not supply the aerospace industry, it is very informative and educational to read this document.

This specification assumes that the user's sensor manufacturer has followed the specification as well as the other indicated specifications that are meant to be a part of it. It also assumes that the information supplied by the sensor manufacturer is

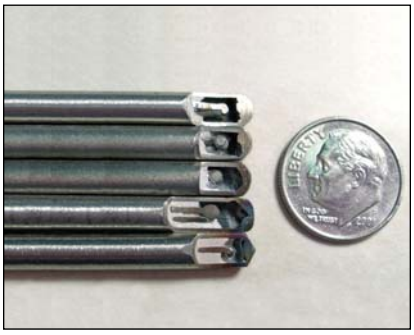

Fig. 1. Only the top two TCs meet the ASTM E608 specification for "measuring junction configuration."

Fig. 2. Cut-away view of a ½-inch NPT, Inconel 601 protection tube welded closed with the wrong material.

Fig. 3. A blown-out or "popcorn" tip resulting from the wrong welding material and internal moisture.

true and accurate. Most of the time it is … but not all of the time.

Mineral-Insulated, Metal-Sheathed Thermocouples

The most common thermocouple type is the MIMS, or mineral-insulated, metal-sheathed thermocouple. This style is also referred to as an MgO style because of the insulation material used – magnesium oxide. ASTM E608: Mineral-Insulated, Metal-Sheathed Base-Metal Thermocouples (and others) are part of AMS 2750D. ASTM E608 specifies the methods of MIMS construction, including the tolerances between the junction and the tip, minimum testing and verification procedures, identification and labeling, and even care in shipping.

While AMS 2750D is rigid in the demands on tolerances required by sensors, there are even more stringent tolerances in place by some aerospace manufacturers. AMS 2750D specifies sensors that are "standard tolerance" and "special tolerance." Some manufacturers' specifications call for ½ special tolerance, ¼ special tolerance and tighter. It is relatively easy to find thermocouple conductors that can be matched together in pairs to meet these specifications. This would be typical when making one of the beaded-wire base-metal thermocouples or insulated platinum-type thermocouples. You would choose matched pairs of conductors to meet the range of temperatures that fit your application.

Making MIMS Thermocouples

MIMS manufacturers, on the other hand, have little control over the outcome of their finished product. Since MIMS goes through a series of drawing-down the outside diameter and annealing (repeatedly) to achieve the correct finished diameters, the conductors go through chemical or molecular changes. What was once thought to be the correct matched conductors can end up being out of tolerance for even standard-tolerance material. While the MIMS producers do the best they can, it is up to the sensor manufacturer to validate the MIMS usefulness for a specific customer.

This is where the certification or testing process comes in. The sensor manufacturer's testing lab – in-house or outsourced – has to check samples of the sensor material through different temperatures to validate the deviation at each temperature. Not every tested material sample passes. Or it should be said that not every sample should pass.

Some sensor manufacturers think that some test results are "close enough" for their customer. Since most sensors are supplied with a certification report assuring their conformance to any number of standards and specifications, and most of these certifications are supplied by ISO 17025 accredited laboratories (many times operated by the same people that made the sensors), why would there be any doubt regarding their serviceability and accuracy?

How would a purchaser of "certified" sensors know how accurate the certified sensors are? The same way we know that other purchased items are what they should be – incoming inspection and spot checks before being used, as well as testing by third-party labs, if necessary.

If you are an ISO-registered company, what does your purchasing process require in section 7.4? It is easy and relatively inexpensive to have a sampling of sensors validated, and you may be pleased to find the same results as listed by your sensor supplier (or not). While the sensor supplier is responsible to you, their customer, it is still the sensor user (you) that is responsible for any bad product produced because of erroneous information. Would your customer accept the excuse of "it's not my fault" regarding a failed process product?

Incoming MIMS Sensor Inspection

It is easy to do an incoming inspection of MIMS temperature sensors by comparing your results with ASTM E608. If they won't meet this basic manufacturing standard, they won't meet any.

- How were they shipped to you? Were they shipped in dust-tight containers or plastic bags? Were they boxed or packed adequately to prevent bending? (E608, para. 10.2)
- Was each thermocouple identified with the manufacturer's name, unique identification number and your purchase-order number? (10.3)
- Were the sensors cleaned before shipping of any grease, oil, dirt, scale or other foreign material? (10.1)

If these criteria are met, you're off to a good start. There are some areas that can't be tested and validated without destroying the thermocouples by taking them apart or by having them X-rayed. Of course spent thermocouples can be dissected for inspection (Fig. 1).

- Check the junction location and size, the distance from the tip and the tip

dimensions (thickness). Was removed insulation replaced? (E608, 6.3.1 & 7)

- The tip itself should be welded closed with a material comparable to the sheath material. (6.2)

Have you had experience with tips burning off while the rest of the sheath remained intact? This would be due to a welding (closing) material that is different than the sheath. This can be tested with a non-destructive metal tester by comparing the metal of the sheath against the metal on the tip. But if your tips have been burning off or breaking off, it has probably been closed with the wrong material. Some manufacturers use a welding material with a lower melting temperature than the sheath because it is easier to work with. If the correct material is used, the tip should last as long as the sheath (Fig. 2).

Have you had any problems with "popcorn" tips? These are tips that seem to have exploded like popcorn when exposed to high temperatures? This would indicate moisture in the closed tip and tips that are thinner than specified in E608, 7.1.2.4. Moisture would become evident during a test for room-temperature insulation resistance (Fig. 3).

To test for room-temperature insulation resistance (IR) a "megger" is used (Fig. 4). This is a special type of ohm meter that uses high voltage to test the insulation resistance between the conductors and the sheath on ungrounded MIMS sensors. On sensors over 0.057-inch O.D., the megger would use 500 volts for this test. There should be a minimum resistance of 1,000 meg ohms, also known as 1 gig, between the conductors and the outer sheath, as specified in ASTM E608, 6.7. Any less indicates that there is moisture or some other contamination in the insulation material. A low-resistance reading will still allow a sensor to give temperature readings, but the accuracy of those readings, as well as the longevity of the sensor, will be compromised. Even if the sensor manufacturer had conducted the IR test before shipping, they could have picked up moisture during shipping or storage (E608, 4.4).

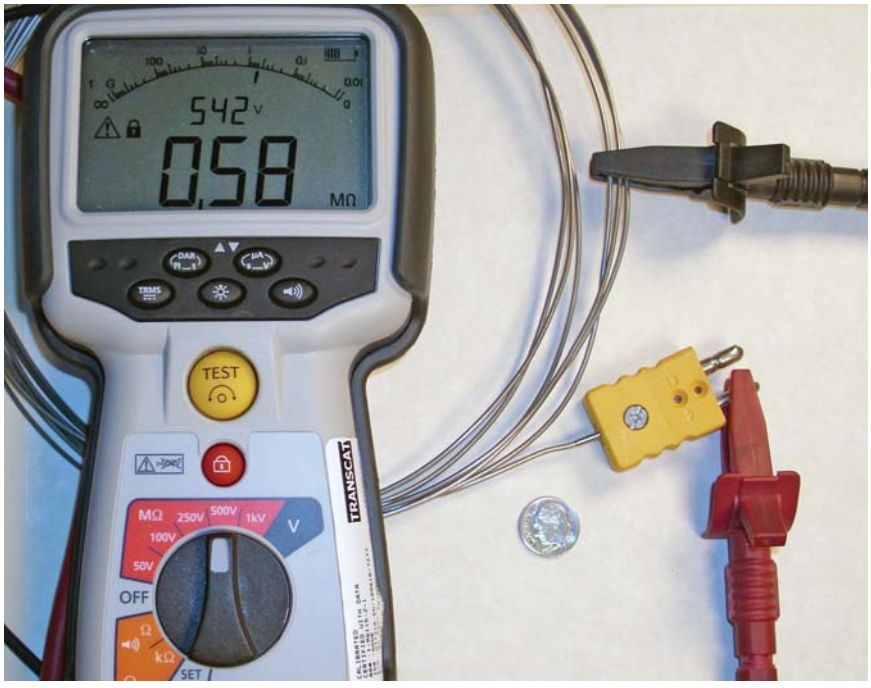

Fig. 4. Room-temperature insulation resistance being tested using a "megger." Note that this TC reads 999.42 megaohms LESS than the ASTM E608 minimum.

Other Sensors

What other type of sensor do you use for your application? Ceramic or glass-fiber-style spools of wire (Refrasil, CEFIR, etc.) are also certified to different temperatures as required. How accurate are those certifications? The only way to verify the accuracy is by using an accredited laboratory – different from the manufacturer/supplier – to test the wire. Different labs will usually have slightly different results, but they will be very close to each other unless the tested product was manufactured with speed and greed.

Platinum thermocouples are the most expensive, most accurate and longest lasting if they are constructed correctly. While they are durable when used correctly and protected adequately, they are very sensitive to contamination. Platinum should never be used in a base-metal or stainless steel outer sheath unless protected by a closed-end ceramic tube. While it is possible to purchase platinum thermocouples in base-metal tubes or sheaths and even platinum MIMS style in base-metal sheaths, they should not be used over 1100°F. Since platinum thermocouples are usually used in temperatures that exceed the limits of base-metal thermocouples, they would typically be utilized well over 1100°F. Another ASTM standard, E2181: Standard Specification for Compacted Mineral-Insulated, Metal-Sheathed, Noble-Metal Thermocouples and Thermocouple Cable, Significance and Use, warns against using platinum-type thermocouples (type S, R and B) in base-metal sheaths. The higher the temperature, the faster that contamination, inhomogeneity and drift will develop. It further states that the results will be inferior to that of a base-metal thermocouple with a base-metal sheath. Just because you can do something doesn't mean that you should. Just because you can combine different materials doesn't mean you should make sensors out of them.

Failing Incoming Inspection

What do you do if you find sensors that don't pass incoming inspection? Stop. Don't use them, and notify your quality manager for follow up with the sensor manufacturer.

Whose job is it to stop a process if you find a problem? It has been found that in 66% of all airplane accidents someone knew or suspected there was a problem, but they were afraid to speak up until afterwards. Whose job is it? It's all of ours. **IH**

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